4/18/88 A1250-1

APRIL 11, 1988

CHEMICAL & ENGINEERING

NEWS

Top 50 chemical products: Volume continues to increase
Page 30

05111 79C098 9 K AR6615SL 1
CONGRESSIONAL INFO SERV-SRI
4520 EAST WEST HWY SUITE 800
SRI ACQUISITIONS
BETHESDA MD 20814

Japan, U.S. Enter New Technology Era

Page 13

CHEMICAL & ENGINEERING NEWS

Volume 66, Number 15
CENEAR 66 (15) 1–78
ISSN 0009-2347

APRIL 11, 1988

News of the Week

■ **House-Senate conferees have completed work on a massive trade bill, but President Reagan may veto the bill unless further changes are made in several provisions the Administration opposes.** **Page 6**

■ **Union Carbide is expected to appeal last week's order by an Indian appeal judge that the company pay $192 million in interim relief to victims of the 1984 Bhopal gas leak.** **Page 7**

■ **Monsanto's G. D. Searle unit has signed a collaborative R&D pact with China's state pharmaceutical administration.** **Page 7**

■ **Monsanto and ICI have reached a settlement that protects Monsanto's glyphosate patents but gives ICI rights to market its own brand of glyphosate pesticide.** **Page 8**

■ **U.S. and West European chemical industry associations have agreed on a set of trade policies they hope will be adopted at international trade talks in Geneva.** **Page 8**

Business

Top 50 chemicals production got back on track in 1987, increasing 5.5% over 1986, partly on the strength of a surge in exports. **Page 30**

Output of polymers—plastics, synthetic fibers, and synthetic rubber—continued to climb last year, hitting a record 57 billion lb. **Page 33**

Avoid building plants leading to another round of overcapacity, petrochemical industry managers were warned at recent international conference in San Antonio. **Page 36**

Government

EPA has proposed new hazardous waste treatment rules that could have a significant financial impact on petroleum refineries and on steel and chlorine producers. **Page 39**

A study of Defense Department science and technology funding finds that basic research support has not kept up with inflation. **Page 43**

Science

Hundreds of Soviet Jewish scientists still seek exit visas, although the pace of emigration approvals has improved recently. **Page 45**

Twist-bent carbon-carbon sigma bonds do exist, according to extensive supercomputer calculations. **Page 50**

Technology

A device that concentrates solar energy into a very intense light beam has been developed at the University of Chicago. **Page 52**

Cover: Five-story pagoda at Kofukuji temple in Nara. Photo by C&EN's James H. Krieger

Letters 4

Concentrates

Business 23
Government 38
Science/Technology 44

The Departments

ACS News 56
Meetings 58
Newscripts 78

News Focus

Despite some huge economic and cultural differences, the U.S. and Japan are increasingly sharing a common technological path, reflected in joint ventures, shared research, and technology exchanges. **Page 13**

Chemical & Engineering News

1155—16th St., N.W., Washington, D.C. 20036

Editor: Michael Heylin
Assistant Managing Editors: David M. Kiefer, James H. Krieger, Janice R. Long, Donald J. Soisson, William J. Storck. **News Editor:** Wilbert C. Lepkowski
Staff Editor: Ernest L. Carpenter
Senior Editors: New York: Earl V. Anderson, Stephen C. Stinson; Chicago: Joseph Haggin; Washington: Doron Dagani, Lois R. Ember, Rebecca L. Rawls, Pamela S. Zurer
Associate Editors: Stuart A. Borman, Mairin B. Brennan, Bette Hileman, Richard J. Seltzer
Service Departments Editor: Dolores Miner
Editing Services: Anne Riesberg (Head), Arlene Goldberg-Gist (Editorial Assistant), Patricia Oates (Administrative Assistant)

News Bureaus: New York: (212) 697-3223 Marc S. Reisch (Assistant Editor). Chicago: (312) 256-4143 Ward Worthy (Head). Houston: (713) 973-8161 Bruce F. Greek (Head). Washington: (202) 872-4495 David J. Hanson (Head). West Coast: (415) 653-3630 Rudy M. Baum (Head). **Foreign Bureau:** London: (01) 540-0414 Dermot A. O'Sullivan (Head), Patricia L. Layman (Associate Editor)
Graphics and Production: Leroy Corcoran (Manager). Alan Kahan (Art Director). Barbara Fryer (Production/Art Director). Linda Mattingly (Staff Artist). Diane Kelly (Costing). **Business Manager:** Arthur Poulos
Circulation Development: Cynthia G. Smith

ADVISORY BOARD: William J. Bailey, Jacqueline K. Barton, Ernest H. Drew, Harry G. Drickamer, A. Nicholas Filippello, Myron Foveaux, Vincent L. Gregory Jr., Adam Heller, John D. Holmfeld, Isabella Karle, Richard Nicholson, Howard A. Schneiderman, Ellen K. Silbergeld, Howard E. Simmons, William P. Slichter

Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-8733
John K Crum, Executive Director

PUBLISHING BOARD: Ned D. Heindel (*Chairman*); *Board of Directors Chairman:* Ernest L. Eliel; *President:* Gordon L. Nelson; John H. Nelson; Louis D. Quin; Jean'ne M. Shreeve; and Barbara G. Wood

© Copyright 1988, American Chemical Society

Subscription & Member Record Service: Send all new and renewal subscriptions with payments to: Controller, ACS, P.O. Box 28597, Central Station, Washington, D.C. 20005. Correspondence and telephone calls for changes of address, claims for missing issues, subscription service, status of records and accounts should be directed to: Manager, Membership & Subscription Services, ACS, P.O. Box 3337, Columbus, Ohio 43210; (614) 421-3776.

For changes of address, include both old and new addresses with ZIP code numbers and mailing label from a recent issue. Allow four weeks for change to become effective. Claims for missing numbers will not be allowed if loss was due to failure of notice of change of address to be received in the time specified; if claim is dated (a) North America: more than 90 days beyond issue date, (b) all other foreign: more than one year beyond issue date; or if the reason given is "missing from files."

Subscription Rates 1988. Printed editions: nonmembers U.S. 1 yr. $49, 2 yr. $83, outside U.S. 1 yr. $75, 2 yr. $135. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3-10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $7.00. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

Advertising Management
CENTCOM LTD.
(For list of offices see page 77)

LETTERS

CHEMICAL SAFETY

Barium acetate precursor

SIR: We would like to bring to the attention of those currently involved in preparing high-T_c cuprate superconductors that a potentially hazardous situation exists when preparing these materials with a barium acetate precursor. Barium acetate is just one of several possible barium precursors for these materials.

A small explosion occurred in our laboratory during the initial heating of a small sample (3 g) of pellets in a tube furnace. The pellets consisted of a dry powder mixture of Y_2O_3, CuO, and $Ba(CH_3CO_2)_2$. Fortunately nobody was injured and no damage was done to the tube furnace. The quartz tube was destroyed. We attribute the explosion to the accumulation in the quartz tube of inflammable pyrolysis products of the barium acetate.

We have learned several lessons from this incident concerning the heating of samples with even small amounts of metal acetate precursors. First, pyrolysis products should not be allowed to accumulate. A sufficient flow of gas, preferably oxygen rich and in a large chamber, should be maintained at all times. Second, oxygen (or other gases) should not be reconnected to a hot furnace. Finally, safety should be considered in evaluating precursors for the new high-T_c superconductors.

Niles Fleischer
Department of Materials Research
Weizmann Institute of Science
Rehovot, Israel

Polonium-210 contamination

SIR: Air ionization devices that contain radioactive polonium-210 are in common use in industry where static electricity must be discharged. Recently, a significant fraction of the 20,000 devices manufactured by 3M have been found to be leaking polonium-210 (C&EN, Feb. 22, page 15).

These devices contain polonium-210 microencapsulated on 35 μm-diameter ceramic beads, which are cemented onto a surface. The intense alpha radiation field ionizes air out to the maximum range of the alpha particles in air—about 5 cm. When they leak, the microcapsules break loose and contaminate the surrounding workplace.

The potential health effects from contamination by this alpha-emitting radionuclide are modulated by several factors. Since alpha radiation cannot penetrate the dead layer of skin on the body, the only hazard is from inhalation or ingestion of the polonium-210. However, since the settling velocity of a 35 μm-particle is about 5 cm per second, it quickly falls to the floor and inhalation is unlikely. Also, since the microcapsules are insoluble, ingested material would pass rapidly through the gastrointestinal tract. That is the good news.

The bad news is that polonium-210 has an oral radiotoxicity similar to that of plutonium. The International Commission on Radiological Protection (ICRP Publication 30) gives the annual limit of intake (ALI) for ingestion of polonium-210 as 3 microcuries, while the value for plutonium-239 is 6 microcuries. Thus, a typical static eliminator containing 40 millicuries equates to over 10,000 oral doses equal to the ALI.

Chemists should be aware of these facts in advising their management about the consequences of polonium-210 contamination from leaking static eliminators.

Wesley R. Van Pelt
President, Wesley R. Van Pelt Associates Inc.
Paramus, N.J.

Darwin's warm little pond

SIR: I was surprised by Bernard Erlanger's assertion (C&EN, Jan. 25, page 3) that Charles Darwin's well-known "warm little pond" statement was intended only as an expression of contempt for the idea of spontaneous generation and was without meaning in regard to the origin of life.

My surprise came from having seen this statement quoted so often as an early, if not the earliest, expression of the contemporary chemical evolution hypothesis. Darwin's statement is largely known as a result of its appearance in a footnote appended by Francis Darwin to a letter written by his father to J. D. Hooker in 1863 (see F. Darwin's "Life and Letters of Charles Darwin"). In this letter the elder Darwin is clearly critical of spontaneous generation; he also states his opinion, as he frequently did, that the question of the origin of life was beyond the scope of latter 19th century science.

However, it is not so clear that Francis Darwin meant to reinforce his father's position on spontaneous generation by footnoting the warm-little-pond statement as Erlanger believes. There are many other statements of Charles Darwin that could have been cited to buttress this point more clearly and force-

U.S., Japan Approach New Era In Science and Technology Relations

Although difficulties and prejudices still abound, a more integrated future for the two nations lies ahead through joint industrial ventures, shared research, and technology exchanges

Wil Lepkowski, C&EN Washington

Despite feverish economic strife and vast cultural gaps, Japan and the U.S. are finding themselves bound on a joint course into a technological future. Conflicts may be hiding the commonalities, but most Americans who have visited Japan and worked within the Japanese technical establishment come away with the feeling that the two countries now share a common path.

Through an elaborate effort to reshape its science and technology policy, Japan is in the midst of a growing technical drive into technologies based on the information sciences and advanced materials fields. The specifics are still being worked out, but every major science policy document, such as Japan's latest White Paper on Science and Technology, underscores Japan's new international role.

For three decades Japan has been a taker in the global technology markets—selling products based on acquired Western know-how while closing its borders to imports. Now it says it wants to return the favors it received while becoming a global powerhouse in basic research.

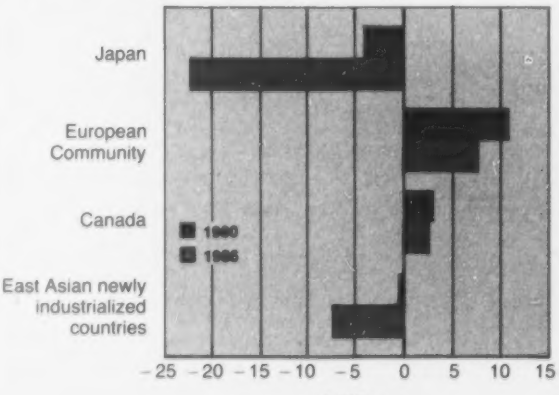
According to Sen. John D. Rockefeller IV (D.-W.Va.), the Japanese ought to start realizing anew that they owe the U.S. a tremendous debt of thanks. Rockefeller majored in Far Eastern studies in college, lived in Japan for several years, has fostered through his activities and Rockefeller family philanthropy Japanese-American understanding over the years, and has sponsored legislation in the Senate aimed at improving Japan-U.S. technical relations.

"We rebuilt Japan as surely as we rebuilt Europe through the Marshall Plan," he says. "If anything, what was accomplished in Japan was even more miraculous. With no democratic traditions, a modern, democratic, free industrial giant emerged."

But Japan took too much an advantage of its growth, Rockefeller believes. "If every nation behaved as Japan has—maximizing exports, minimizing imports, practicing what amounts to mercantilism—the international system would have collapsed years ago." Now, Rockefeller adds, the situation has gotten so economically out of balance that "economic growth in the U.S. now depends on Japanese willingness to lend us tens of billions of dollars yearly to finance our budget deficit and overconsumption."

Japan has begun taking steps, as outlined in its landmark Maekawa report on restructuring the economy. The U.S., with a trade deficit with Japan last year of $60 billion, naturally wants more than words of intention from the Japanese. Although Japan already has dropped one trade barrier after another—a big breakthrough was Japan's agreement two weeks ago to open up its big construction projects to American bidders—the pressure is on the Japanese to lower other barriers that keep American consumer items

U.S.'s largest trade deficit in high-tech products is with Japan



priced prohibitively high to Japanese. Japan has established policies to do that.

Japan, meanwhile, has never been able to abandon its feeling of dependence on the U.S. But it doesn't quite trust America either. Its fear is that an impulsive U.S. will abandon its "protection" of what is to Japanese perceptions a weak, fragile, and small island nation. In contrast, disturbing reports reach the public of renewed Japanese arrogance toward the West's inability to keep pace technologically with Japan.

The reality is that the open, blunt Americans and the hierarchical Japanese with their intricately codified nonverbal mannerisms have never known one another very well. And they still don't. What they have, though, are the common language needed in the doing of science and technology and a certain common purpose as world leaders among the democracies.

Japan's Prime Minister Noboru Takeshita talks of a new sense of furusato, or "hometown," policy of enriching the domestic economy and social spheres and in the process widening the volume of imports. Japan's new economic "dream" includes big public works programs, such as the vision of a new capital to be built some distance from super-expensive and overcrowded Tokyo. Japan's fiscal 1988 budget calls for $54 billion worth of public works projects. Takeshita's major priority is to push through a tax policy that can pay for the internal changes he has in mind.

Although the new policy may not open Japan's doors to American high-tech products immediately, it already has for such products as California wines. U.S. high-tech companies, such as those producing value-added specialty chemicals, are just beginning to study what an upgraded Japanese consumer economy will mean for them.

The fact of Japan and the U.S. as scientific and technological partners has been played down against the tense political rhetoric of today. The spectacle of U.S. congressmen battering with sledge hammers a Toyota automobile in front of the U.S. Capitol is by now the public's stereotypical image of the state of relations. And Toshiba Machine's sale of fabrication technology to the Soviet Union for the rapid manufacture of submarine propellers is seen in the U.S. as a modern form of Japanese treachery. More recently fears have grown that the Japanese are purchasing America's assets through investments in U.S. corporations and real estate.

"I see the relationship with Japan becoming worse," warns Michael B. Smith, deputy U.S. trade representative in a recent interview with the *Journal of Commerce* newspaper. "As they grow more and more powerful, they're going to be less and less willing to make deals."

Although the Japanese profusely apologized for the Toshiba incident, they regard the overall mood in the U.S. as unrealistic Japan-bashing and are bothered by it. They say a lot of the accusations are true, but add that most of them are unfair, a reflection of U.S. deficiencies, and they stress that in any case they are changing. The situation between the two countries is such a complex mixture of fact, fancy, and sheer cultural misperceptions that issues have to be dissected carefully to assess the true nature of the relationship. Outlining the "togetherness" aspect seems long overdue.

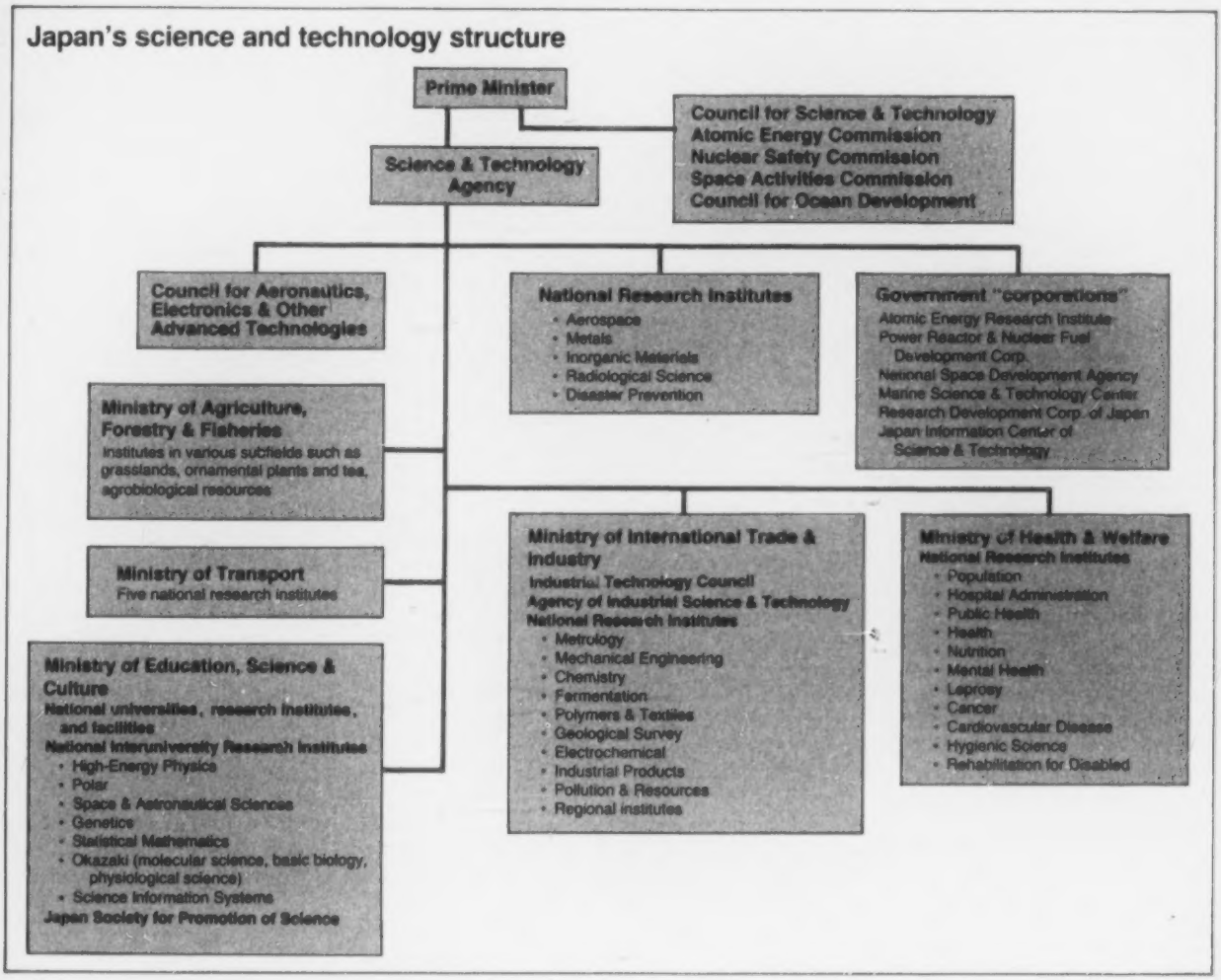
The signs of this togetherness include:

- The willingness of the Japanese to begin putting up money in international research ventures, such as in their revamped Human Frontiers Program that would make a global assault on the mysteries of human biology, from brain function to molecular immunology.
- The extensive network of research, development, and marketing collaborations between corporations in the two countries. Patent litigation is picking up, too, but this phenomenon doesn't contradict the intermingling of interests.
- Growing interest among Americans in understanding the Japanese language and culture. More than 20 Japan-America societies exist in the U.S., with growing membership and active programs.
- Spirited competition among the states to attract Japanese manufacturing companies. States with full-time offices in Japan now number 36.
- Frequency of meetings and conferences on the subject of Japan-U.S. relations in technology and science.
- A soaring interest among American corporations in learning more about how Japanese companies manage technology and the ways they have redefined the meaning of "basic research." Dow Chemical has stationed seven persons in its technology office in Tokyo, strictly to monitor Japanese advances and make connections with Japan's innovators.
- Enormous American dependence on the Japanese for advanced military technology. This is naturally a source of conflict and embarrassment to the U.S. The new FSX fighter would contain almost all Japanese

Japan spends less than half what U.S. does on R&D

	U.S.	Japan
R&D expenditures	$100.4 billion (1986)	$40.0 billion (1985)
As % of GNP	2.7%	2.8%
Nondefense as % of GNP	1.8%	2.8%
% financed by industry	50% (1985)	67% (1985)
Basic research as % of total R&D	12% (1986)	13% (1985)
Nonacademic scientists and engineers	2.844 million male 334,000 female	1.444 million male 69,800 female
% foreign students science	18.2% (1984–85)	0.7% (1983–84)
% foreign students engineering	21.7% (1984–85)	1.1% (1983–84)
Patents granted in U.S.	47,077 (1970) 46,715 (1975) 37,356 (1980) 33,896 (1983) 38,124 (1986)	2,625 (1970) 6,352 (1975) 7,124 (1980) 8,793 (1983) 13,209 (1986)

Source: National Science Foundation



components. But the U.S., fearing further trade imbalance, won't let the Japanese build it.

In short, though tensions exist and in some areas will probably get even worse, the U.S. and Japan already globally oversee a complementary technological empire, or "technopolis" as termed by Dataquest Semiconductor's Sheridan Tatsumo.

The process of Japanization has been, of course, accelerating over the past 20 years in the U.S., with the influx of Japanese transistor radios, textiles, and steel, then—in a jump to mid- to high tech—cameras, automobiles, video and stereo equipment, semiconductors, and personal computers. The blessings to Americans of that "invasion" were naturally mixed. Consumers liked products of high quality, elegant design, and low price. At the same time, traders and economists became terrified over the political and economic implications. In the high-tech area, only chemicals seemed to be maintaining a U.S. advantage, with a consistent 2.5:1 ratio of exports over imports. Meanwhile, Japan was getting rich.

Some economists feel that Japan will become so powerful that the world will be forced to divide itself into three large, exclusive trading blocs consisting of the Americas, Europe, and Japan. Others, such as Japanese technology expert Ellen L. Frost of Westinghouse Corp. and author of the book, "For Richer, For Poorer—the New U.S.-Japan Relationship," believes such projections are now simply passé. She believes the two financial and commercial systems are so intertwined that such a phenonemon is practically impossible.

One factor in favor of the "new alliance" is that Japan is determined never again to be an aggressive military power. Its future lies instead in international cooperation. Its constitution forbids militarizing, Japan wants no part of it, the world—the Soviet Union and China especially—won't tolerate it. In fact, some historians have said that the Japanese felt inwardly relieved to have lost World War II because defeat, though hideously punctuated by the atomic explosions over Hiroshima and Nagasaki, rid Japan once and for all of its expansionistic warlord tradition. Shoguns and their loyal samurais take a new form in Japan's pursuit of its new economic dream as the captains and sergeants of industry and technology.

And they're so good at it that they give people chills.

"Every time I've gone with a group to Japan over the past two or three years to visit research leaders, laboratories, and universities," observes materials scientist Rustum Roy of Pennsylvania State University, "we come out of the rooms saying, 'My God, how are we ever going to catch up with them in R&D?' As of now, their research in the field of materials is head and shoulders above anything we are doing. The R&D plants they are installing today have no equivalent in this country."

Roy believes that once the Japanese switch fully into gear in superconductivity R&D, the U.S. will hardly stand a chance to compete head to head. "To think there is any U.S. company that can compete with the Toshibas, Sumitomos, Mitsubishis, and Kyoceras in this field in making commercial products is ridiculous. No one here would have the strength to stay in the business long enough to sustain the up-front money. If any company dared spend the amount of money needed, it would be the victim of a corporate takeover. In fact, if you ask me, it is Wall Street that's the villain here. It's the enemy of American R&D."

There are dozens of reasons, all set down in current writings, why the Japanese are so good. Individuals find their identities in groups. They are an island nation bent on survival. Workers give total loyalty to their companies. Salaries of corporate officers are nowhere near those of their counterparts in the U.S. Decisions are made by consensus, from the bottom up. The Japanese character pays passionate attention to detail. Engineers push design to the limits of efficiency, elegance, and miniaturization. Japanese plainly want their products to be the best anyone can make. They know how to manage technology. Their companies know how to cooperate in sharing technology with one another. Yet they compete for markets with no holds barred.

That combination is too little understood, says political scientist Richard Samuels, director of Massachusetts Institute of Technology's highly touted Japan program, which gives science and engineering students Japanese language training and the opportunity to spend up to a year in Japanese laboratories.

Says Samuels, "The mystery is how they are able to defy economic theory. The Japanese companies have found a way to cooperate in research while being wildly competitive with each other."

Herbert Fusfeld, director of the Center for Science & Technology Policy at Rensselaer Institute of Technology, says Japanese engineers are more versatile than their American counterparts. "The Japanese stay in one company and move there from function to function. In U.S. companies you have that traditional division between product and process. U.S. engineers don't tend to move from one group to another, and this gives the Japanese a real advantage. Everyone is doing everyone else's job over time."

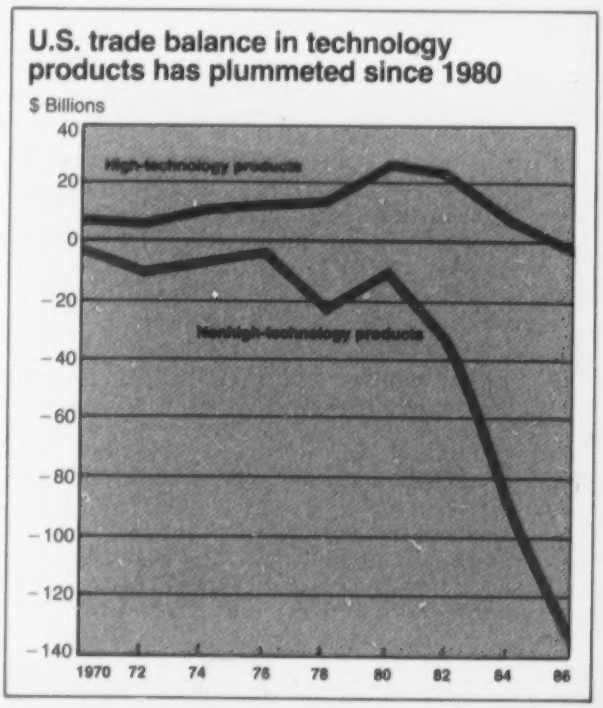
Justin Bloom, president of Technology International Inc., who for years served as science adviser at the U.S. embassy in Tokyo, has taken special interest in the Japanese practice of consensus building.

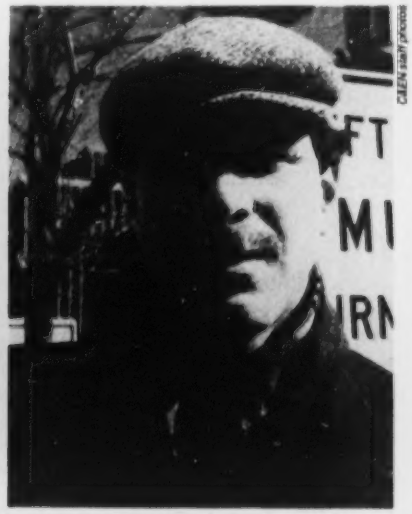
"One thing most Americans can't comprehend about the Japanese is that consensus building is not a top-down process for them," he explains. "They call it a bottom-up process. The key decision-making level in Japan is in what they call the kacho—typically five to 10 lower-level management people who act as a filter in bringing information to the top man. If those young guys—30 to 40 years old—don't think the idea is good, it never sees the light of day. The people upstairs don't get involved in the sordid details."

National Science Foundation policy analyst Robert S. Cutler, who recently spent a year studying technology transfer processes in Japan as a Fulbright fellow, says a further magic lies in the "small country" atmosphere in Japan.

"Some people notice that Japanese companies seem to sell similar products," he says. "It looks a lot like they might be collaborating on the designs and specs. That's because high-tech Japan is a small country and all the engineers know each other. When one company starts something, even the company presidents call each other to discuss it. And Japanese companies don't suffer from the 'not invented here' syndrome that so hobbles U.S. innovation. Instead, they are eager to please their customers and would rather get their people involved in making something better for the marketplace."

Another quality is patience on the part of the institutions that fund industrial research in Japan. For example, Hitachi, in its drive to develop advanced software, has accumulated a reservoir of $4 billion from its parent banks to fund the R&D work needed





C&EN staff photos

Rockefeller (left): Japan took too much advantage of its growth. Frost (middle): three-bloc idea now passé. Samuels: how firms defy economic theory is mystery

to make the leap to the next generation of that technological art form.

According to Sheridan Tatsuno, senior industry analyst for Dataquest's Semiconductor Industry Service, Japanese companies have resigned themselves to losses "over the next five years" as they regroup toward the creation of Japan's "technopolis strategy for the 21st century." Tatsuno made his remarks last fall at a symposium on U.S.-Japan technology exchange sponsored by the Japan-America Society of Washington, D.C. As a reflection of the new awareness of technological Japan, the society is reorienting much of its program to serving corporate interests. The symposium's papers have just been published.

At the same symposium, Gerald Dineen, vice president, science and technology, for Honeywell, offered his assessments of Japanese incentives for innovation. "We emphasize the movement and manipulation of numbers on a ledger," he says. "Japan emphasizes the movement and manipulation of products. Japan's unique capital markets allow corporate senior management to make longer-term investment decisions. Japanese corporations are highly leveraged; hostile takeovers are almost unheard of in Japan; and Japanese investors take the long view and, in many cases, favor reinvestment of capital over increased dividends." He didn't add, in this respect, that workers hold a substantial amount of corporate stock in Japan.

Most observers believe that the Japanese have the most catching up to do in basic science. They apparently know it, and a recent report on U.S. and Japanese education systems confirmed it. One reason why American technical scholars make so little use of Japanese literature is that their bibliographies contain predominantly U.S. and West European citations.

The problem of Japanese scientific creativity was underscored by MIT immunologist Susumu Tonegawa, who shared the Nobel Prize in Medicine last year. Tonegawa openly criticized the Japanese research system for stressing conformity at the expense of the imaginative boldness that comes from individuality in U.S. and West European research. He said he had to come to the U.S. to give his mind full flower and that Japan, unless it changes, would continue to be handicapped with respect to creative science.

Japanese native Leo Esaki of IBM, winner of the 1973 Nobel Prize in Physics for his discovery of the tunnel diode, has more specific things to say about the basic research mentality in Japan.

"A traditional value system that is as widespread as in Japan is not easily or quickly changed. . . . Japan has produced no great philosophers. Novelists and poets, yes—but generally the Japanese are uncomfortable with abstract concepts. Their instincts are more emotional than philosophical; they try to capture the world by intuition rather than by logic.

"It is true that in many cases group-oriented societies work very nicely. They can be wonderful production factories. . . . But the price you pay in such a controlled environment is a lack of creativity. Since scientific creativity is the most important element in basic research, it comes as no surprise that Japan lags behind. This is not because applied research has received undue emphasis—it is simply that basic research cannot be done. The Ministry of Education thinks that if you have plenty of money, you can do what you like. The Japanese do not like to hear me say this, but money is not enough. If you are not your own master, if you do not have your own soul, you will be an object rather than a creative subject."

Roy has a contradictory view. He thinks the term basic research is going to acquire a new 21st century meaning under Japanese influence. "We are in a new era now," says Roy, "where technology is driving science. Most of the Nobel Prizes now are going to discoveries that are either based on technology or embody it. I think it was a basic research development of the highest magnitude that Japan mastered the

transition process from science to technology. Japanese creativity is different. We shouldn't judge them on outmoded standards. There is enough 'basic research' on the shelf to keep Japan going for the next 50 years."

Samuels adds that Japan has always been an adaptable society and it will therefore find a way to change its educational structure to promote individual creativity. Experimental schools already exist, he says, for that purpose.

Over the past year, the word, "symmetrical" has come into vogue in scientific relations between the two countries. A meeting in Hawaii next month between Japanese and U.S. scientists and industrialists will be defining the word in terms of technical exchange. The gathering is being sponsored by the National Academy of Sciences and the National Academy of Engineering. It will offer each side a chance to discuss most of the significant cultural differences between the two countries.

Many such meetings have been occurring in the past few months and practically everyone involved thinks they're needed.

Vastly different notions of symmetry had been hampering the negotiations between the U.S. and Japan over the renewal of a Presidential-level scientific exchange agreement in process for about a year. But U.S. negotiators, led by White House science adviser William R. Graham, decided it was time to redefine the framework of U.S.-Japan relations in science and technology and set about reworking the agreement. After six meetings, final wording was reached on March 30 and President Reagan and Prime Minister Takeshita are expected to sign the agreement by June.

The specifics will not be released until then, say State Department sources. But the Japanese agreed to admit more American researchers to their university and government laboratories and to help out in language training. Specific areas of collaboration were agreed upon in all the areas of research crucial to both countries—from biotechnology to advanced software. American negotiators hoped to jimmy open Japan's dynamic industrial laboratories for exchange, but such a practice was left up to the companies to work out individually.

What really hampered the talks was American insistence that intellectual property and national security practices be better spelled out. In the end it was decided, not surprisingly, that rights to inventions would follow the rules of the host country. In essence, says a government source, "if you're doing a joint project, you divvy up the patent rights."

The basic principle was that the widest possible distribution of information and equipment be the practice, though subject to export control laws of each country.

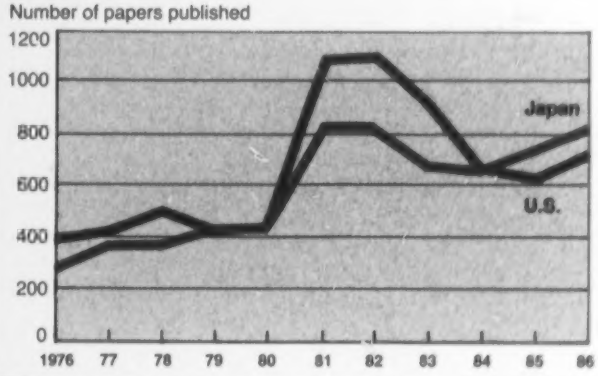
What was groundbreaking about the agreement was not so much its components but the fact that the Japanese and Americans were able to agree on a written framework for all future government-sponsored relations.

What the pressure by Graham has done, according to Charles T. Owens, head of the National Science Foundation's international division, is to spur the Japanese to change their habits. Although the Japanese are not willing to be bullied, they are, Owens says, "scouring the landscape for opportunities to make us feel better about the science and technology relationship and where it is going."

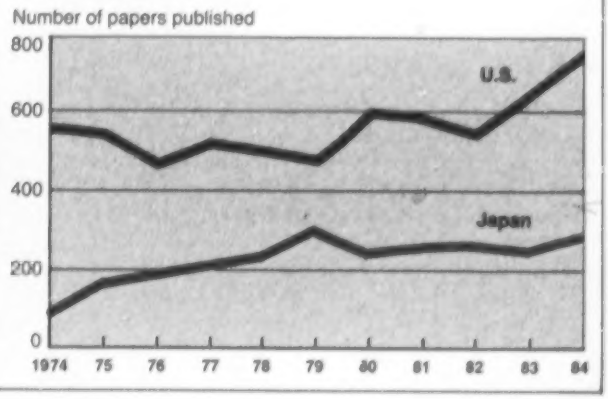
Owens spent three years as head of NSF's Tokyo office. He is currently helping administer the recently announced $4.4 million grant by the Japanse to NSF for supporting scientists wishing to do research in Japan. He also issues a series of translations of Japanese science policy developments. The series is the most complete source of policy-related science and technology developments in Japan's national laboratories, universities, and industry.

Fusfeld (left): Japanese engineers are more versatile than U.S. counterparts. Bloom (above): consensus building a bottom-up process. Cutler: further magic is small country atmosphere

Japan has surpassed U.S. in ceramics R&D activity ...



...but U.S. remains dominant in catalysis work



A countertrend to the cooperative mood in Washington is a continuously rising protective—as opposed to protectionist—attitude by U.S. government officials toward American science and technology. Although corporations are collaborating on one level, the government is taking pains to restrict information to Japanese who visit and work in government laboratories, pending assurance that American visitors are given reasonably free access to Japanese research. The provisions will be spelled out in the *Federal Register* sometime this month.

Thus, because of the intense competition in technology, government-sponsored research is coming to be seen as a commodity with a price and a value. And this trend cannot but intensify.

What may not be intensifying but is at least increasing is the interest by American companies in Japanese technology. Use of Japanese literature has not taken off yet, by any means, with University Microfilms recently having ended its hopes of marketing a translation service of Japanese journals. Business interest simply wasn't that high.

The key component in technology transfer, as Cutler has pointed out in his study of university-industry technology transfer in both countries, is person-to-person interaction. Dow Chemical, which operates a seven-person technology office in Tokyo—the largest such operation among chemical companies in Japan—finds the people it wants to know by first scanning Japanese patents.

Up until last month, the office was run by Mark Kelly, who is now retired and living in Santa Fe, N.M. The Dow operation is small compared with counterparts in the electronics field. However, the big difference is that Dow seeks out cooperative ventures with the Japanese. The other companies run, as he puts it, "G-2 operations," World War II parlance for clandestine work designed to outwit an adversary.

Patents Dow concentrates on, says Kelly, involve mainly biotechnology and pharmaceuticals, engineering plastics, membranes for separation processes, and fine ceramics. These are fields Dow is trying to develop a future in to go along with such primary areas as drugs, agricultural chemicals, epoxy resins, urethane chemicals, and polystyrene foams in which Dow already has a strong market position there.

"The point is to target technologies we want access to," he says, "and places we want to establish relations with. These mainly involve 140 chemical, rubber, and steel companies, along with university and government research labs. We think we've had good success with all of them."

Once a target for a new relationship is selected, contact is made with the board of directors of the Japanese facility to arrange a visit. Kelly would usually present a basic slide show about Dow and its global interests. The activity has led in the past three years to about 60 visits by Dow people to Japan, and around 75 visits to Dow by Japanese industrialists. Kelly says every manner of relationship is discussed, from joint ventures to licensing of technology. About a dozen formal technology exchanges have been worked out since the office opened in 1984.

Kelly says it isn't wise to publicize Dow's office in Japan, where modesty is a highly valued virtue. "It's not how you do business there," he says. He adds that the Japanese chemical industry is much more cooperative than either the automotive or electronics industries. "I guess it's because chemical companies all over the world have to compete with as well as sell to one another."

American companies have had a presence in Japan since the Meiji Restoration of 1868 when Shogun rule during the 200-year Tokugawa period came to an end and Japan decided to become an international nation.

Eastman Kodak, for example, set up shop in 1869, and despite its embarrassing loss of the 35-mm camera market to the Japanese, remains one of the biggest American profit-makers there through the sale of sophisticated photographic equipment in the medical and scientific fields. It has learned to sell, trade, borrow, and license with the Japanese, and now is in the midst of relearning consumer camera technology from the Japanese.

Those companies with a long-time presence in Japan seem to have the edge in whatever patterns take form. But other American firms have a lot to learn, as much about Japan as about what they should be about.

Says Westinghouse's Ellen Frost, "American companies are too wrapped up in short-term mentality and perceptions. Industry is not at all willing to hire the people and put up the money to understand Japan. Few U.S. companies have a 10- to 15-year strategic plan that corresponds in any way to what the Japanese do. If you lift the lid off, though, you see a lot of joint ventures and cross-licensing. The U.S. still has a 3-to-1 advantage in cross-licensing. So there's a lot of irony in the situation."

The extent to which U.S. and Japanese high-tech firms are collaborating is surprising once that "lid" is lifted. The most complete study of those relations was recently published by Fusfeld's RPI center in a project directed by Lois Peters entitled "Technical Network Between U.S. and Japanese Industry."

Peters' report—234 pages rich in detail and insight—covers various types of alliances involving robotics, machinery and machine tools, energy, information processing and electronics, chemicals, pharmaceuticals and biotechnology, and metals.

A fascinating portrayal in her report is that of Motorola, one of the more successful American "competitors" with the Japanese. Motorola's strategy is to have its fingers in every important pie in electronics. It is involved in the Defense Department's multi-industry very high speed integrated circuit program, with the Microelectronics and Computer Technology consortium in Austin, Tex., with Stanford University's university-industry computer-information sciences program, and the Semiconductor Research Corp. in North Carolina.

That is only the beginning. Motorola also has alliances with Hitachi and Toshiba through MITI's national R&D programs, and with Europe's government-university-industry ESPIRIT program that has hopes of giving Europe parity with Japan and the U.S. in electronics and information sciences. In short, Motorola is the prototypical component of that "technopolis" Tatsumo says is emerging.

The phenomenon scrambles the meaning of competing. "Who is going to compete with whom?" Peters asks. "Is there such a thing as a technological winner? It is most likely that growing international technical cooperation will result in even more rapid diffusion of technology, leaving firms to compete on an equal technological base with other factors becoming increasingly important.

"The popular concept of U.S. and Japan competing as countries is more pragmatically a complex mix of competition among individual companies using technology from others, or competitions among binational teams. Technical alliances can strengthen corporate actions even as they confuse national policies."

Ohio is a case in point. The state, with 94 Japanese companies now located there, is celebrating an enormous expansion of industrial ties with Japan. Most recently, Honda Motor Co. announced plans to break ground for a new $380 million assembly plant adjoining the earlier plant built in 1979 near Marysville. Construction began on March 21. Ohio has nothing but praise for the marriage of its labor pool with Japanese technology and management.

And so do Ohio's bankers, who see no danger from any Japanese takeover of assets in their state. During a conference last fall held by the Japan-Midwest Association in Columbus, Jerry V. Jarrett, chairman of Ameritrust Corp. of Ohio, said he was looking ahead to further "interconnecting webs of productive relationships" between Japan and the states.

After first reviewing the acknowledged problems of U.S. deficits and Japanese insularity, he said the world would never be the same again. "We stand today on the threshold of an exciting new period of international alliances of all kinds, from licensing and joint ventures to full-scale mergers and acquisitions."

"Companies everywhere," he said, "are experimenting with new ways to expand their global reach in the most efficient ways possible. With modern communi-

How U.S. and Japan rate in key research areas

Substance and materials

U.S. leads in . . .
- Performance under extreme conditions
- Surface boundaries
- Theoretical design techniques
- Theories of reaction for syntheses
- Compounding materials

Japan leads in none of the areas designated

Electronics

U.S. leads in . . .
- Molecular electronics
- Bio-electronics
- Artificial intelligence software

Japan leads in . . .
- Optoelectronics

Life sciences

U.S. leads in . . .
- Design and synthesis of functional proteins
- Micromanipulation of DNA and chromosomes
- Cell manipulation
- Brain mechanism studies
- Immunology

Japan leads in none of the areas designated

Production and processing

U.S. leads in . . .
- Computer software

Japan leads in . . .
- Robotics
- Very large scale integrated circuits
- High-precision work

Both are about even in . . .
- Computer hardware

Source: Japanese government surveys

Sampling of collaborations of U.S. companies with Japanese firms

CHEMICALS

Hercules/Sumitomo Chemical: Sumitomo licenses conductive elastomer technology for keyboard data entries.

Diamond Shamrock/Showa Denko: joint venture to produce agricultural chemical and veterinary drugs.

Du Pont/Nissan Chemical Industries: Du Pont uses Nissan s high-density polyethylene technology to develop third-generation HDPE resin.

Olin/Kanegafuchi Chemical Industry: Olin licenses ion exchange caustic soda technology.

Air Products & Chemicals/Daido Sanso: Daido serves Air Products markets in Pacific region.

W. R. Grace/MTP Kasei: joint venture to produce and market variety of chemicals, including soundproof materials, rust preventives, and adhesives.

Celanese/Nippon Shokubai: joint venture to develop synthesis-based processes for petrochemicals.

PHARMACEUTICALS/BIOTECHNOLOGY

Bristol-Myers/Kyowa Hakko: Bristol-Myers licenses rights to develop and sell anticancer drug mitomycin C.

Abbott/Hokuriky Seiyaku: Abbott licenses bronchodilator, Bremax.

Merck/Yamanouchi Pharmaceutical: Merck licenses urinary infection antibacterial Noroxin.

Merck/Torii & Co.: Merck acquires majority interest.

Genentech/Kyowa Hakko and Mitsubishi Chemical Industries: joint venture to produce tissue plasminogen activator using Genentech methods; Japanese firms to provide financing and do clinical trials.

Schering-Plough/Yamanouchi Pharmaceutical: Yamanouchi licenses α-interferon manufacturing technology.

Genex/Green Cross: exclusive 15-year license for Green Cross to market Genex's human serum albumin from microbial strain.

Genetic Systems/Daiichi Pure: exclusive rights for Daiichi to sell for research only certain Genetic Systems monoclonal antibodies.

Source: Rensselaer Polytechnic Institute

cations and international markets, technology has a way of diffusing itself around the world like salt in water. Trading partners like the U.S. and Japan have to live with each other with a degree of openness and shared values which is unprecedented in the histories of either nation."

Yet, only last month, the CBS Evening News was reporting instances on the West Coast of Japanese firms laying off Americans first, and Japanese second in a marketing downturn. Is it the beginning of a pattern? Or is it merely an episode? It is events such as that, or the manner in which they are reported, that will continue to sow distrust between the two countries.

So after more than two decades of perceiving a "threat" from Japan's technological advances, the U.S. seems to be coming to the point of viewing Japan with clearer eyes. But, as MIT's Samuels points out, contact is still difficult. American pride is hurt by Japanese success. Japan in its way does not really like the feeling of being number one in anything and thus is uncomfortable with any leadership role.

Cutler says he observed during his year in Japan, though, a new young breed of Japanese technical professionals, ones who have managed to acquire Western habits of direct personal communication without the protection of lengthy ceremony. And, says Brian Moore, a researcher at the Japan External Trade Organization in New York, they seem to enjoy it. "When they get used to interacting with Americans," he says, "they begin to open up. They find it to be easier to be more straightforward. They find they enjoy the freedom in being able to speak up right away."

Adds Frost, "There's no question that the Japanese need foreign pressure because they've had long-entrenched elites and an insular mentality left over from the past. They have that group-oriented system that keeps out not only foreigners but other Japanese. It s hard for new businesses to break into their clubby structure. So they need pressure from the outside to break down those barriers.

"They're the first nonwhite country to get into the white man s club. But they need us, for our markets, for our universities, for our sciences, for our agriculture and raw materials. Their elites think we are the pillar of free trade and investment. They feel there is no meaningful alternative to the U.S.

"And though they are a monoculture with a deep pride in their race, they are an extremely pluralistic society. They have a legal and flourishing communist party. The gap between the old and the young is as wide as anywhere in the world. There is a whole generation with no memory of World War II. It's a tremendously cacaphonic society with all kinds of openness. Its press is relentless in exposing corruption."

But with all the cacaphony is that singular vision in Japan of getting better at what it chooses to excel in. It may feel as though it is still a nation of rice farmers needing their subsidies to survive, but its real power is in technology.

As Dineen says in his Japan-America Society paper, "The Japanese offer the long-term perspective necessary to push basic research to its fruition. American individualism, however, is most likely to provide the 'spark of genius' that makes basic research successful. Both countries, therefore, should work together to gain the rewards that appropriate cooperative endeavors in basic science and technology can bring."

A concluding point RPI's Peters makes in her report cautions U.S. policy makers against overreacting to a technologically potent Japan. "The ties with Japan can be used to invigorate and complement our vast resources," she says. "One can liken the situation to a muscle cramp. The worst antidote is to tighten up." □

Top 50 Chemicals Production Turned Back Up in 1987

Output increased 5.5% after slipping slightly in 1986 as organic chemicals moved up 5.5% and inorganic chemicals rebounded to rise 4.9%

Marc S. Reisch, C&EN New York

A surge in exports of chemicals last year helped boost U.S. chemical output dramatically. According to C&EN's annual ranking of the 50 largest-volume chemical products, total production in that group in 1987 increased 5.5% from 1986 to 567 billion lb. This marked a dramatic improvement over 1986 when total production of the Top 50 chemicals dropped 0.9% from the previous year.

The recovery was all the more dramatic considering that last year imports continued to grow, but at a much slower rate than they did in previous years. A decline in the value of the dollar helped make U.S. chemicals more attractive to overseas purchasers, and thus U.S. export volume increased markedly.

Demand in the U.S. markets for chemicals did little to produce the dramatic improvement in overall chemical production. The housing market was virtually flat. The auto market was down moderately. However, the U.S. farm economy began to stir and showed some small signs of improvement.

Among the largest-volume chemicals produced in the U.S., sulfuric acid continued to reign as king, with production last year totaling 77.5 billion lb, a 5.2% increase from 1986. Nitrogen continued to rank a distant second, with production at 47.3 billion lb, down 2.7% from 1986.

Organic chemicals, comprising 36% of the Top 50, made a good showing, but that segment of the Top 50 did not do so well as it did in 1986. Production of those substances increased 5.5% from 1986, compared with a 9.3% year-to-year increase in 1986. Between 1982 and

About the Top 50 list of chemical products

Government data, trade association figures, and industry estimates all go into preparing C&EN's annual list of the Top 50 chemical products, ranked by production volume. The federal government is relied upon most heavily, but when government figures are not available, other sources, primarily trade associations, are used. Industry sources and C&EN estimates are used only when other data are lacking.

Government data are not always accurate—they are only as good as the information that individual companies report. But they are an objective measure of production extending back many years. Therefore, relatively accurate indications of growth can be made on a consistent basis.

At this time of year, C&EN has access only to preliminary reports of production for 1987. When the government and trade associations issue their final reports, the outcome can be changed, sometimes dramatically. As a result, the production figures for earlier years that appear in the table on page 31 are different in some cases from those published in last year's Top 50 report. The final reports also can affect the rankings of chemicals. The 1986 rankings of 16 chemicals listed in the table, for example, are different from those in the similar table published by C&EN a year ago (C&EN, April 13, 1987, page 20).

The list itself covers production figures for the U.S. and includes chemicals produced for export. Candidates for the list include all basic, intermediate, and chemically homogeneous finished products. These range from chemical building blocks like ethylene and propylene to downstream products like vinyl acetate and ethylene glycol.

The roster also includes basic inorganic chemicals, but does not include what C&EN considers to be minerals, such as salt, gypsum, and sulfur. Lime is included because it is processed and has many chemical and industrial applications. Refractory (dead-burned) dolomite is excluded in the calculations of lime production.

In the organics list, such petrochemical feedstocks as ethane, butane, and propane are excluded arbitrarily because they are considered to be products of oil companies and because they have many nonchemical uses.

There are other gray areas besides lime and petrochemical feedstocks. For example, the basic aromatics—benzene, toluene, and xylene—are included. Admittedly, this makes the list less pure chemically.

Production figures are published by the government and trade associations in a variety of units—millions of pounds, thousands of tons, billions of cubic feet, millions of gallons, metric tons. To provide an accurate ranking and to make comparison of production volumes easier, C&EN not only gives production in common units but converts production to billions of pounds as well.

Top 50 chemicals production totaled 567 billion lb in 1987

Rank 1987	Rank 1986[a]		Billions of lb 1987	Billions of lb 1986	Common units[b] 1987	Common units[b] 1986	Average annual growth 1986–87	1985–86	1982–87	1977–87
1	1	Sulfuric acid	77.49	73.64	38,748 tt	36,822 tt	5.2%	−7.1%	3.1%	1.1%
2	2	Nitrogen	47.32	48.62	653 bcf	671 bcf	−2.7	2.4	6.2	8.5
3	4	Ethylene	34.99	32.81	34,992 mp	32,811 mp	6.6	9.9	7.4	4.5
4	6	Ammonia	32.32	28.01	16,161 tt	14,005 tt	15.4	−19.1	0.5	−0.3
5	3	Oxygen	32.28	33.03	390 bcf	399 bcf	−2.3	1.5	2.2	0.2
6	5	Lime[c]	30.36	29.67	15,182 tt	14,834 tt	2.3	−6.1	1.5	−2.2
7	7	Sodium hydroxide	23.03	21.38	11,517 tt	10,691 tt	7.7	−1.9	4.2	0.9
8	8	Chlorine	21.93	20.87	10,963 tt	10,436 tt	5.0	0.4	3.6	0.5
9	9	Phosphoric acid	20.95	18.41	10,473 tt	9,206 tt	13.8	−12.5	4.9	2.8
10	10	Propylene	18.53	17.34	18,527 mp	17,343 mp	6.8	16.5	8.1	6.3
11	11	Sodium carbonate[d]	17.78	16.88	8,891 tt	8,438 tt	5.4	−1.8	2.6	5.5
12	14	Urea[e]	14.86	12.06	7,431 tt	6,029 tt	23.3	−9.7	2.8	6.6
13	13	Nitric acid	14.20	13.12	7,102 tt	6,562 tt	8.2	−10.9	−0.8	−0.9
14	12	Ethylene dichloride	13.81	14.53	13,805 mp	14,529 mp	−5.0	20.1	12.6	5.6
15	15	Ammonium nitrate[f]	12.83	11.11	6,416 tt	5,556 tt	15.5	−18.0	−2.0	−1.1
16	16	Benzene	11.67	10.23	1,585 mg	1,389 mg	14.1	8.9	8.5	1.1
17	17	Carbon dioxide[g]	9.84	9.77	4,922 tt	4,883 tt	0.8	−2.3	5.2	9.6
18	18	Ethylbenzene	9.41	8.92	9,409 mp	8,915 mp	5.5	20.7	7.2	5.0
19	19	Vinyl chloride	8.23	8.42	8,230 mp	8,415 mp	−2.2	−11.1	10.9	3.8
20	21	Terephthalic acid[h]	8.11	7.68	8,110 mp	7,684 mp	5.5	18.4	10.9	1.2
21	20	Styrene	8.09	7.84	8,090 mp	7,838 mp	3.2	2.8	6.4	2.5
22	22	Methanol	7.29	7.33	7,292 mp	7,327 mp	−0.5	46.5	−0.7	1.6
23	25	Toluene[i]	6.73	5.82	928 mg	802 mg	15.7	14.7	5.4	−0.7
24	24	Formaldehyde[j]	6.08	5.89	6,077 mp	5,885 mp	3.3	5.0	4.8	1.1
25	26	Xylene	5.72	5.55	795 mg	771 mg	3.1	4.5	3.9	1.0
26	23	Ethylene oxide	5.62	5.94	5,623 mp	5,943 mp	−5.4	9.4	2.4	3.0
27	27	*p*-Xylene	5.15	5.00	5,152 mp	4,995 mp	3.1	4.5	9.9	5.9
28	28	Hydrochloric acid	4.99	4.83	2,495 tt	2,413 tt	3.4	−14.0	0.4	−0.2
29	29	Ethylene glycol	4.52	4.76	4,515 mp	4,759 mp	−5.1	13.9	0.9	3.1
30	30	Ammonium sulfate	4.37	4.17	2,183 tt	2,086 tt	4.7	−0.3	4.3	0.8
31	31	Cumene	4.15	3.70	4,151 mp	3,695 mp	12.3	10.5	8.6	4.3
32	41	Methyl *tert*-butyl ether[k]	3.37	2.24	3,372 mp	2,237 mp	50.7	18.3	32.6	nm
33	33	Phenol[l]	3.24	2.92	3,241 mp	2,921 mp	11.0	5.2	9.9	4.3
34	32	Acetic acid	3.23	2.93	3,227 mp	2,931 mp	10.1	1.2	3.3	2.7
35	35	Butadiene[m]	3.00	2.59	3,002 mp	2,593 mp	15.8	10.8	9.4	−1.5
35	34	Potash[n]	3.00	2.65	1,360 tmt	1,202 tmt	13.1	−7.3	−5.3	−4.6
37	35	Carbon black	2.72	2.59	2,724 mp	2,585 mp	5.4	0.5	3.4	−1.0
38	37	Propylene oxide	2.61	2.48	2,608 mp	2,480 mp	5.2	3.3	9.2	3.6
39	39	Acrylonitrile	2.55	2.31	2,551 mp	2,314 mp	10.2	−1.4	4.6	5.3
40	40	Vinyl acetate	2.51	2.25	2,505 mp	2,249 mp	11.4	6.5	6.0	5.4
41	38	Aluminum sulfate	2.45	2.44	1,223 tt	1,222 tt	0.1	−3.6	1.2	0.2
42	42	Cyclohexane	2.25	2.07	2,250 mp	2,071 mp	8.6	25.0	12.0	0.3
43	43	Acetone	2.08	1.94	2,082 mp	1,936 mp	7.5	8.3	4.2	1.1
44	44	Titanium dioxide	1.90	1.86	952 tt	931 tt	2.3	8.3	7.7	2.9
44	45	Sodium silicate	1.90	1.57	948 tt	786 tt	20.6	9.0	7.4	2.4
46	47	Sodium sulfate[o]	1.61	1.55	805 tt	775 tt	3.9	−6.3	−1.4	−4.2
47	48	Adipic acid	1.57	1.52	1,572 mp	1,522 mp	3.3	4.7	6.3	0.4
48	46	Calcium chloride[p]	1.55	1.56	773 tt	780 tt	−0.9	−2.6	−2.0	−4.3
49	49	Isopropyl alcohol	1.31	1.28	1,313 mp	1,275 mp	3.0	3.2	−1.0	−3.8
50	50	Caprolactam	1.16	0.85	1,161 mp	850 mp	36.6	−21.5	7.9	4.1
		TOTAL ORGANICS	281.85	269.17			5.5%	9.3%	7.1%	2.7%
		TOTAL INORGANICS	284.83	267.74			4.9%	−5.7%	2.3%	−0.1%
		GRAND TOTAL	566.68	536.91			5.5%	−0.9%	4.8%	1.3%

a Revised. b tt = thousands of tons, bcf = billions of cubic feet, mp = millions of pounds, mg = millions of gallons, tmt = thousands of metric tons. c Except refractory dolomite. d Natural and synthetic. e 100% basis. f Original solution. g Liquid and solid only. h Includes both acid and ester without double counting. i All grades. j 37% by weight. k Production data for earlier years unavailable. l Synthetic only. m Rubber grade. n K_2O basis. o High and low purity. p Solid and liquid. nm = not meaningful.

1987, production of organic chemicals among the Top 50 increased 7.1% a year. Over the long term, however, their output has grown at a much slower pace. Between 1977 and 1987, output of organic chemicals among the Top 50 has grown only at a rate of 2.7% a year.

However, the inorganic segment of the Top 50 made a dramatic recovery in 1987. Production increased 4.9%, following a 5.7% decline in 1986. Within that segment, output of the major fertilizer chemicals was up—including phosphoric acid, up 14%; urea, up 23%; and potash, up 13%. Other big-volume inorganics also showed improvements. Nitric acid production increased 8.2%, and ammonium nitrate production increased 16%.

Of the Top 50 chemicals, production of 42 of them increased in 1987. By contrast, production of only 19 increased in 1986. Although total production of the Top 50 chemicals, at 567 billion lb, was up 5.5% from 1986, it was down 1.4% from the Top 50 historical high of 575 billion lb in 1979. The 1987 production level was 22% higher than the decade-low production level of 464 billion lb registered in 1982.

For the Top 50 group, composite output increased at a compound annual rate of 4.8% between 1982 and 1987. However, indicative of long-term growth, Top 50 production grew at an average annual rate of 1.3% between 1977 and 1987.

As a group, organic chemicals outperformed the inorganics, however. Showing the largest production increase on the organics side was methyl *tert*-butyl ether. Production of that chemical was up 51% to 3.37 billion lb. The gain pushed that chemical to 32nd place in 1987 from 41st place in 1986.

Next in terms of percentage gains among the organics was caprolactam, up 37% to 1.16 billion lb. The increase gained the chemical's entry into the Top 50 at 50th place in 1987. It did not appear on the list for 1986 (C&EN, April 13, 1987, page 20).

Also up appreciably in terms of percentage gains were urea, with output up 23% to 14.9 billion lb following a 9.7% decline in 1986; butadiene, up 16% to 3.0 billion lb; toluene, up 16% to 6.73 billion lb; and benzene, up 14% to 11.7 billion lb.

Not all the organics gained, however. The biggest decreases came from ethylene oxide, whose production was down 5.4% from the previous year, and ethylene glycol, down 5.1%.

For inorganic chemicals, 1987 production was led by sodium silicate, up nearly 21% from 1986 to 1.90 billion lb. Sodium silicate also led the pack in production growth in 1986, when production grew 9.0%. Also showing very good production increases in 1987 were ammonium nitrate, up 16% to 12.8 billion lb following an 18% decline the previous year; and ammonia, up 15% to 32.3 billion lb following a 19% decline in 1986.

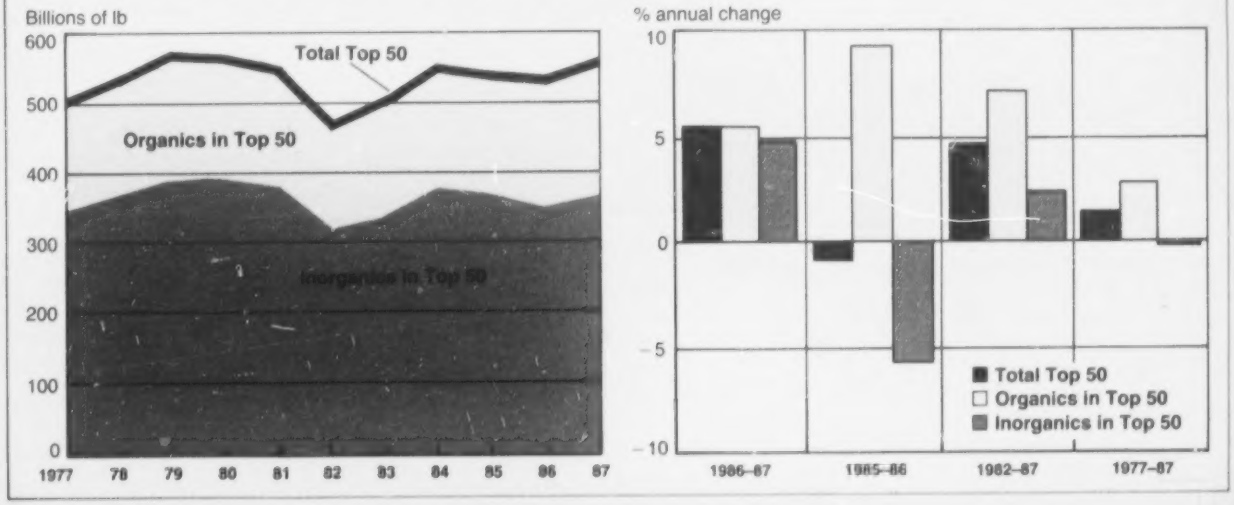
Other large-volume inorganic chemicals that had large swings in production last year were phosphoric acid, up 14% to nearly 21 billion lb, following a 13% decline a year earlier; and potash, up 13% to 3.0 billion lb in 1987 following a 7.3% decline in 1986.

Over the past five years, 43 of the Top 50 chemicals have registered increases in production. Leading in individual increases over the five-year span was methyl *tert*-butyl ether, whose production grew at an annual compound rate of almost 33%. Next were ethylene dichloride, up about 13% annually for the five-year period; cyclohexane, up 12% a year; vinyl chloride, up 11% a year; and terephthalic acid, also up 11% a year.

On the downside of production, leading the products with the largest individual decreases over the five-year period was potash, whose output fell at a compound annual rate of 5.3%. Other chemicals registering decreases over the five-year period were ammonium nitrate, down 2.0% a year; calcium chloride, also down 2.0% a year; sodium sulfate, down 1.4% a year; and isopropyl alcohol, down 1% a year.

Looking at growth over the past 10 years, 39 of the Top 50 chemicals have recorded overall production

Production of Top 50 chemicals is on the upswing



increases. The best long-term performer has been carbon dioxide, whose output grew at an annual compound rate of 9.6% during this period. Production of nitrogen also grew at a remarkable rate of 8.5%. Other chemicals with sizable growth rates were urea, up 6.6% a year, and propylene, up 6.3% per year.

Potash registered the greatest average annual rate of decline over the past 10 years. Its output has fallen at a compound annual rate of 4.6%. Other products with shrinking output were calcium chloride, down 4.3% a year; sodium sulfate, down 4.2% a year; isopropyl alcohol, down 3.8% a year; and lime, down 2.2% a year.

The group comprising the 10 largest chemical commodities in terms of production was the same in 1987 as it was in 1986. Some commodities within that group, however, switched places in ranking. Ethylene, for example, which ranked third in volume in 1987, was fourth in terms of production in 1986. Ammonia moved up to fourth place from sixth place a year earlier. Oxygen moved down to fifth place from third place in 1986, and lime slipped a notch to sixth place after ranking fifth place a year earlier.

There was a good deal of rank shifting thoughout the rest of the list. In all, 21 of the chemicals either moved up or down in the rankings.

Besides the rise for ethylene and ammonia and the fall of oxygen and lime already noted, there were other significant changes. Some upward movements included methyl *tert*-butyl ether, with its 51% increase in production in 1987, which jumped to 32nd place from 41st in 1986. Other large changes included urea, which jumped to 12th place from 14th, and toluene, which moved up to 23rd place from 25th. □

Polymer output records fifth consecutive annual rise

Overall production of plastics, synthetic fibers, and synthetic rubber polymers reached a record high of 57 billion lb in 1987. The growth marked the fifth consecutive annual increase for the product group, lifting the output total 9.1% above the 1986 record.

Plastics, which account for more than two thirds of the polymer group production totals, continued their buoyant growth in 1987. Production was up 9.9% from 1986. The strongest growth among plastics was registered by the thermoplastic resins, up 10%. Of such resins, polypropylene continued to show the highest growth, up 14%; followed by high-density polyethylene, up 12%; polyvinyl chloride and copolymers, up 9.9%; low-density polyethylene, up 8.3%; and polystyrene, up 7.7%.

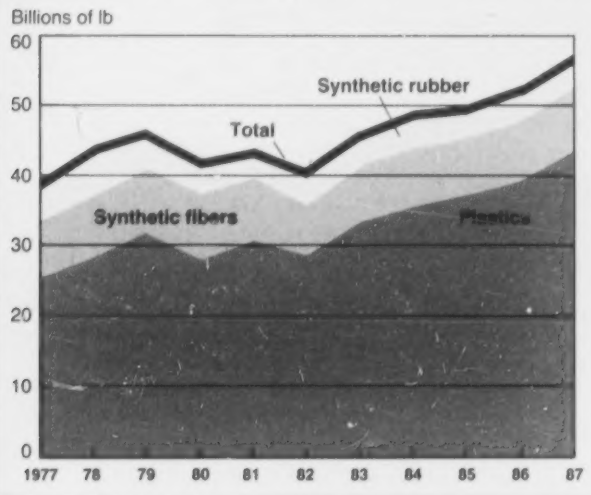
By comparison, output of thermosetting resins grew 7.4% in 1987. Melamine resins made a spectacular recovery in 1987, up 23%, following a dismal performance a year earlier when production dropped 9.9%. Production last year at 212 million lb marked a decade high for melamine resins production. The previous high was in 1984, when industry produced 210 million lb of the resins.

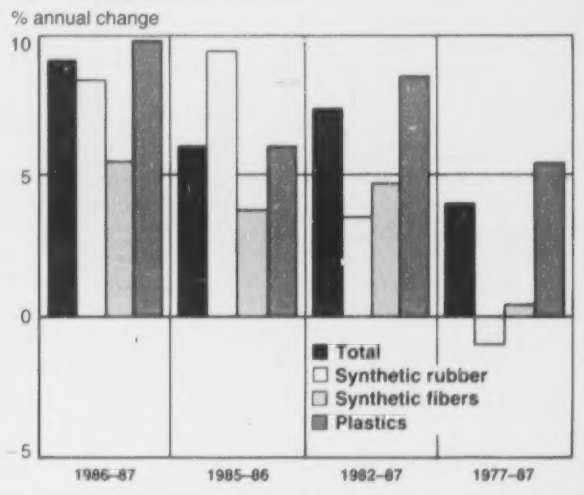
Showing good though less remarkable gains were epoxy resins, up 8.8% in 1987; urea resins, up 8.7%; polyesters, up 7.8%; and phenol and other tar acid resins, up 5.4%.

For the five-year period between 1982 and 1987, the plastics segment grew at an annual compound rate of 8.5%. For the 10-year period between 1977 and 1987, plastics grew at an annual compound rate of 5.4%.

Synthetic rubber output increased 8.4% in 1987. Production of 4.8 billion lb last year matched the 4.8 billion high of 1984, but the category's output is still running 17% below the decade high of 5.6 billion lb in 1979.

Output of plastics, synthetic fibers, and synthetic rubbers continued to climb in 1987





Total polymer production exceeded 57 billion lb last year

	Billions of lb		Common units					Average annual growth			
	1987	1986	1987	1986	1985	1982	1977	1986–87	1985–86	1982–87	1977–87
PLASTICS (millions of lb)											
Thermosetting resins	**6.26**	**5.83**	**6,266**	**5,834**	**5,631**	**4,367**	**3,943**	**7.4%**	**3.6%**	**7.5%**	**4.7%**
Phenol, other tar acid resins	2.87	2.72	2,869	2,721	2,621	2,060	1,458	5.4	3.8	6.8	7.0
Urea resins	1.38	1.27	1,382	1,271	1,210	998	963	8.7	5.0	6.7	3.7
Polyesters (unsaturated)	1.37	1.27	1,370	1,271	1,223	865	1,061	7.8	3.9	9.6	2.6
Epoxies (unmodified)	0.43	0.40	433	398	385	286	261	8.8	3.4	8.6	5.2
Melamine resins	0.21	0.17	212	173	192	158	200	22.5	−9.9	6.1	0.6
Thermoplastic resins	**37.03**	**33.57**	**37,028**	**33,569**	**31,525**	**24,425**	**21,569**	**10.3%**	**6.5%**	**8.7%**	**5.6%**
Low-density polyethylene	9.63	8.89	9,629	8,888	8,889	7,503	6,471	8.3	−1.1	5.1	4.1
PVC and copolymers	7.97	7.26	7,971	7,256	6,772	5,326	5,253	9.9	7.1	8.4	4.3
High-density polyethylene	8.00	7.17	7,999	7,171	6,671	4,928	3,652	11.5	7.5	10.2	8.2
Polystyrene[a]	4.78	4.44	4,782	4,442	4,054	3,191	3,446	7.7	9.6	8.4	3.3
Polypropylene	6.65	5.81	6,647	5,812	5,139	3,477	2,747	14.4	13.1	13.8	9.2
TOTAL[b]	**43.29**	**39.40**	**43,294**	**39,403**	**37,156**	**28,792**	**25,512**	**9.9%**	**6.0%**	**8.5%**	**5.4%**
SYNTHETIC FIBERS (millions of lb)											
Cellulosics	**0.61**	**0.62**	**605**	**619**	**556**	**584**	**888**	**−2.3%**	**10.9%**	**0.7%**	**−3.8%**
Rayon	0.41	0.40	414	404	353	388	598	2.5	14.4	1.3	3.6
Acetate[c]	0.19	0.22	191	215	205	196	290	−11.2	4.9	−0.5	−4.1
Noncellulosics[b]	**8.30**	**7.82**	**8,298**	**7,815**	**7,564**	**6,442**	**6,911**	**6.2%**	**3.3%**	**5.2%**	**1.8%**
Polyester[d]	3.54	3.31	3,541	3,305	3,341	3,168	3,642	7.1	−1.1	2.3	−0.3
Nylon	2.69	2.51	2,688	2,514	2,343	1,927	2,326	6.9	7.3	6.9	1.5
Olefins[e]	1.48	1.38	1,478	1,380	1,249	723	234	7.1	10.5	15.4	20.2
Acrylic[f]	0.59	0.62	591	616	631	624	709	−4.1	−2.4	−1.1	−1.8
TOTAL[b]	**8.90**	**8.43**	**8,903**	**8,424**	**8,122**	**7,026**	**7,799**	**5.6%**	**3.8%**	**4.8%**	**0.4%**
SYNTHETIC RUBBER (thousands of metric tons)											
Styrene-butadiene[g]	1.87	1.75	850	792	735	876	1,395	7.3	7.8	−0.6	−4.8
Polybutadiene	0.82	0.74	371	336	330	288	361	10.4	1.8	5.2	0.3
Ethylene-propylene	0.56	0.51	254	230	215	123	158	10.4	7.0	15.6	4.9
Nitrile	0.15	0.13	69	59	53	45	70	16.9	11.3	8.9	−0.1
Other[h]	1.41	1.31	638	596	505	497	433	7.0	18.0	5.1	4.0
TOTAL[b]	**4.81**	**4.44**	**2,182**	**2,013**	**1,838**	**1,829**	**2,417**	**8.4%**	**9.5%**	**3.6%**	**−1.0%**

a No longer includes acrylonitrile-butadiene-styrene or styrene-acrylonitrile resins; historical data are restated. b Totals are for those products listed. Totals may not add because of rounding. c Includes diacetate and triacetate yarn, but does not include cigarette tow. Beginning with 1985, includes rayon yarn. d Excludes aramid after 1982. e Includes olefin film, olefin fiber, spud-bonded polypropylene, and vinyon. f Includes modacrylic. g Excludes high-styrene latex. h Beginning with 1985, includes neoprene; historical data are restated. Also includes butyl; polyisoprene; chlorosulfonated polyethylene; polyisobutylene; and acrylo, fluoro, and silicone elastomers. **Sources:** Society of the Plastics Industry, Textile Economics Bureau, Rubber Manufacturers Association

All segments of the synthetic rubber category registered increases in production in 1987. Nitrile rubber showed the largest rise at 17%, following a 11% increase in 1986. Both polybutadiene and ethylene-propylene rubber production grew 10% in 1987. The increase in polybutadiene production was the most remarkable, following a 1.8% increase in 1986. Ethylene-propylene rubber's 1987 growth follows a 1986 growth of 7.0%.

Production growth of styrene-butadiene rubber slowed in 1987 to 7.3% from a 7.8% growth rate in 1986. Also putting in a showing that was not quite as good as the year earlier were the synthetic rubber products reported as a group by the Rubber Manufacturers Association: neoprene; butyl; polyisoprene; chlorosulfonated polyethylene; polyisobutylene; and acrylo, fluoro, and silicone elastomers. Production of that group grew 7.0% in 1987, compared with 18% in 1986.

Over the past five years, the synthetic rubber category has not grown so rapidly as it has in the past two years. Synthetic rubber production has grown at an average annual rate of 3.6% over the past five years. For the past 10 years, production has actually declined at an average annual rate of 1.0%.

Though still the slowest-growing of the entire polymers product group, synthetic fibers nevertheless recorded a respectable production increase of 5.6% in 1987 over the year-earlier level. Despite continued pressure from imported textiles, noncellulosics showed the most impressive gains. Howeven, cellulosics declined in part because of discontinuation of U.S. triacetate production.

Output of noncellulosics recorded the best gain, rising 6.2% in 1987. The group accounted for more than 90% of total fiber production last year. Olefins continued to lead in growth; they were up 7.1% in 1987. Matching that rate of increase was polyester; staple and filament production both grew in 1987. The recovery for polyester followed a 1.1% decline in 1986. Nylon was up 6.9% in 1987 as demand for new generation broadloom continued. The only poor showing was from acrylic fiber, production of which continued to flounder. Output dropped 4.1% in 1987 following a 2.4% decline in 1986. □